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Direct Observation of Multi-Band Physics using Quantum Phase Diffusion in 3D Optical Lattices SEBASTIAN WILL, THORSTEN BEST, SIMON BRAUN, ULRICH SCHNEIDER, LUCIA HACKERMÜLLER, DIRK-SÖREN LÜHMANN, IMMANUEL BLOCH, Johannes Gutenberg-University Mainz

— In recent years ultracold atoms in optical lattices have shown their potential to simulate condensed matter quantum systems. A prominent example was the realization of the superfluid to Mott insulator transition, which has theoretically been described by a *single-band* Bose-Hubbard model. Recent theoretical studies, however, have emphasized, that interatomic interactions may bring multi-band effects into play and considerably modify the behaviour of ultracold atomic systems. In our experiment we have trapped a BEC of ^{87}Rb atoms in a 3D optical lattice with minimal underlying harmonic confinement. A rapid increase of the lattice depth allows us to follow the quantum phase diffusion of the macroscopic matterwave field, showing a continuous collapse and revival, whose period is determined by the onsite interaction energy. The observed dynamics give striking evidence of multi-band physics beyond the single-band Hubbard model, our data being in excellent agreement with numerical exact diagonalization. We have extended this experimental method to tunable ^{87}Rb-^{40}K Bose-Fermi mixtures and could elucidate distinct effects of interspecies interactions.

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